

# *ADVANCED COMMUNICATIONS TECHNOLOGY*

## AMSC Satellite System Test Report

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Systems Directorate**

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## 1. Introduction

One of the objectives of the Mobile Communications Infrastructure project is to conduct in-depth evaluations of mobile satellite systems that appear to meet Coast Guard communications requirements. The goal in testing these systems is to quantify how well they work and to provide some metrics to see how each of these systems could fit the needs of the Coast Guard. There are a variety of parameters we will measure for each system. Most of the measurements will be of the overall system, not the individual pieces. These will include coverage, availability, reliability, accuracy, interoperability, bandwidth, latency, ease of use, and cost. Some testing will be performed in the Advanced Communications Lab at the R&D Center, and some will be performed by placing systems on operational units for field testing.

## 2. AMSC System<sup>1</sup>



American Mobile Satellite Corporation (AMSC) is the single L-band domestic mobile satellite service (MSS) provider licensed by the FCC. They provide low bit-rate voice and data service throughout the continental United States (CONUS) as well as Alaska and Hawaii.

AMSC has its genesis in NASA's MSAT-X program in the late 1970's and early 1980's. In 1985 the FCC allocated frequencies for domestic mobile satellite service and twelve applications were filed. At WARC 87, the frequencies were allocated internationally. The FCC decided to license only a single domestic MSS and instead of a spectrum sharing arrangement or spectrum auction, they forced the applicants to combine. Eight of the original twelve did so in 1988, and in 1992 the FCC licensed the AMSC consortium.

The Canadian counterpart to this system is the MSAT system owned and operated by Telesat Mobile Inc. (TMI). TMI's satellite, ground network, and user terminals are identical to AMSC's. The original agreements between the two companies called for them to provide backup to each other.

### 2.1 Ground Segment

AMSC operates a single earth station in Reston, VA. This also serves as the network control center (NCC). All links into the Public Switched Telephone Network (PSTN) are made through the Reston facility. All calls to mobile terminals are made by directly dialing the terminal's toll-free number. This initiates a call through the PSTN to the earth station and then via the satellite to the mobile terminal.

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<sup>1</sup> Most of this section is reprinted from the USCG R&D Center report "Technology Assessment of Mobile Satellite System Alternatives," April 1998.

## 2.2 Space Segment



*Figure 2-1 AMSC-1 Satellite*

The original plan was to eventually have three geostationary satellites in orbit. The first at 101°W, then later adding 62°W and 139°W. AMSC launched their first satellite, AMSC-1 in April of 1995 to the slot at 101°W. AMSC currently has control of one other orbital slot, but no plans to launch an additional satellite. In fact, due to slow customer growth, in December of 1997, AMSC signed agreements to lease their satellite to African Continental Telecommunications Ltd. and purchase a 50% interest in TMI. All of AMSC customers will now be served via TMI's satellite, MSAT-1, located at 106.5°W. African Continental will move AMSC-1 to a new location over Africa. TMI might move MSAT-1 to the 101°W orbital slot. Both MSAT-2 and AMSC-1 have 6 L-band spotbeams (AMSC-1 actually only has 5 due to a transponder failure). These enable coverage of CONUS out to 200 NM offshore, and Alaska, Hawaii, and the Caribbean. As with any GEO system, coverage of Northern Alaska is limited since the look angle to the satellite becomes lower than the horizon at high Latitudes.

## 2.3 User Segment

Mobile terminals come in a variety of types and sizes. The main difference between the units is the type of antenna: tracking for vehicle, maritime and aeronautical applications, whip for vehicles, flat panels for portable units, and dishes for fixed sites. Mobile terminals are manufactured by five companies.

- Westinghouse Electric (land mobile and maritime mobile units)
- Mitsubishi Electric (land mobile and maritime mobile units)
- Trimble Navigation (mobile data terminal)
- KVH (maritime units and antennas)
- CAL Corporation (aeronautical units)

All units work in the same manner; they function similar to a cellular phone. The user dials a PSTN number directly, the call goes through the satellite, to the earth station, and is connected

through the PSTN. Since the system is digital, data connections can be made without the use of a modem. The terminals all have RS232 interfaces to allow external devices such as a computer to connect to the terminal and place a data call.

## **2.4 Market**

AMSC currently has about 30,000 customers, mostly concentrated in the vehicle tracking and dispatch market. AMSC's original market was thought to be cellular fill-in, however in the ten years between when the FCC allocated the frequencies and AMSC launched their satellite, cellular systems went through a massive expansion and the cellular fill-in market largely disappeared. Currently AMSC is targeting maritime, aeronautical, emergency communications restoration, search and rescue, SCADA, fleet management and dispatch applications.

## **2.5 Westinghouse Series 100 terminal<sup>2</sup>**

Westinghouse Satellite Communications Products is one of the two main manufacturers of terminals for AMSC. They make terminals in maritime, fixed site, and mobile versions. An aeronautical version of the Westinghouse terminal is manufactured by CAL Corp<sup>3</sup>. All of the variants are similar in construction and capability. The main difference between them is the antenna. Detailed specifications of the Westinghouse terminals are included in Appendix A.

A Westinghouse satellite telephone consists of the following basic elements: the handset with hands-free clip-on microphone, the transceiver, the antenna electronics unit, and an antenna. Included with the basic system elements are the mounting brackets and cabling. Depending on the application requirements, a Westinghouse satellite telephone operates with one of seven different types of antennas.

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<sup>2</sup> Westinghouse Wireless Solutions Co. web site at <http://165.117.246.101/index.html>

<sup>3</sup> CAL Corp web site at <http://www.calcorp.com/satcg.htm>



*Figure 2-2 Westinghouse Series 100 Terminal: Transceiver, Handset, Antenna Electronics Unit, and two different antennas.*



*Figure 2-3 Westinghouse Series 100 Handset and Transceiver*

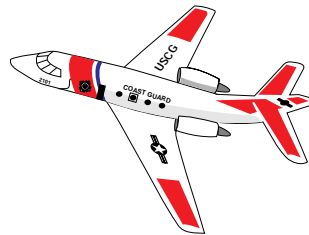


*Figure 2-4 Westinghouse Series 100 Antenna Electronics Unit*

All testing conducted by the R&D Center was done using Westinghouse Series 100 terminals. The aeronautical terminal was tested by the R&D Center during the Operational Information System (OIS) Phase II project<sup>4</sup> and was also used for the Operational Web Link (OWL) project<sup>5</sup>. A mobile version with the mast antenna was used for testing in the Advanced Communications lab. Various maritime versions were tested by TISCOM under a bailment agreement with AMSC.

A new service being offered is the packet data service. This is currently available through the Canadian (TMI) Earth Station only so it was not able to be tested. Since TMI and AMSC have merged operations, this service should be offered through AMSC's Reston Earth Station soon. Appendix A-3 contains information on this new service.

### 3. System Testing



*Figure 3-1 HU-25 Falcon Jet*

The AMSC system was used for several projects and therefore information on the performance of the system can be found in several reports. Four aeronautical terminals were installed on HH-60 Jayhawk helicopters at AIRSTA Cape Cod. These were used for the OIS Phase II and OWL projects during 1996-1997. Aeronautical terminals are currently installed on four HU-25 Falcon jets at AIRSTA Cape Cod for voice and data usage. A mobile terminal with mast antenna has been installed at the R&D Center for testing in the lab since 1996. Coast Guard TISCOM conducted a test and evaluation of the AMSC system using several cutters scattered throughout the Coast Guard. AMSC provided several maritime terminals (Westinghouse, Mitsubishi, and KVH) to the Coast Guard for free under a bailment agreement. This testing ended December 1997 and a report should be forthcoming from TISCOM.

For all lab tests, the Westinghouse mast antenna was located on the air conditioner, outside the lab window; a clear view to the satellite was possible from this location. The antenna was adjusted for the Latitude range of the R&D Center. All calls were placed from the Westinghouse unit, through the AMSC-1 satellite, and to AMSC's Reston, Earth Station.

#### 3.1 Voice Testing

No formal voice testing was done on the AMSC system by the R&D Center. This was to be accomplished by TISCOM as part of their evaluation.

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<sup>4</sup> Information on the OIS/2 project is contained in the OIS/2 Evaluation report available from the R&D Center.

<sup>5</sup> Information on the OWL project can be found at <http://comms.rdc.uscg.mil/OWL.html>



## **3.2 Data Channel Testing**

Bit Error Rate (BER) testing was done to assess the raw performance of the data communications channel. In addition, we wanted to measure how well the system performed when the signal strength was degraded. In the field this could be caused by blockage, interference, operating at the edge of the satellite footprint, or signal fading. In the Lab this was simulated using attenuators.

The call connection time for data calls was about 22–25 seconds total. It typically took 5 seconds for the modem initialization, 12–13 seconds for the call to be connected through the Earth Station and the remote end to ring, and then about 5–7 seconds for the modems to synchronize and establish the data connection.

### **3.2.1 Test Bed**

Bit Error Rate (BER) testing of the Westinghouse Series 100 unit was accomplished by using the Series 100 to place a data call to a modem in the Advanced Communications Lab. The physical channel was established between the Series 100 and the modem in the lab. The data transfer scheme was established and controlled by a pair of Network Communications Corporation (NCC) Network Probes model NP6650, one connected to the Series 100 and one connected to the modem in the. The transmission path for the data tests thus went from the NP6650 to the Series 100, to the satellite, to the LES, through the PSTN, to the telephone extension in the Lab, to the modem and then to the other NP6650. Since the channel is full duplex, data was transmitted in both directions simultaneously. This is illustrated in Figure 3-2 below.

In order to vary the signal strength of the connection, variable attenuators were added inline between the Series 100 transceiver and the antenna.



Figure 3-2 AMSC Data Channel Testing Diagram<sup>6</sup>

### 3.2.2 BER Tests

A data call was established by remotely controlling the Series 100 with the NP6650 using a serial interface and standard AT command sets. Although the carrier is modulated at 6.4 kbps, the AMSC system has a maximum data transfer rate of 4.8 kbps; the rest of the bit rate is used for error control and correction. Once a 4800 bps data connection was established between the Series 100 and the remote modem, both NP6650s were switched from VT100 terminal emulation to Bit Error Rate Test (BERT) mode. In the BERT mode, the NP6650s transmitted and received standardized data packets. The tests were conducted for periods of about 75–80 minutes using the 511-bit pattern. The bit errors, character errors, bit count, character count, elapsed time, errored time, forced errors, time out of synchronization, severely errored seconds (SES), degraded minutes (DM), BER, and Character Error Rate (CER) were all recorded. The data recorded on the NP6650 connected to the Series 100 represents the AMSC receive data and the data recorded on the NP6650 connected to the remote modem represents the AMSC transmit data (contained in Appendix B).

A series of tests were conducted starting with the system tuned for maximum signal strength. This was used as the 0 dB reference. Then the variable attenuators were used to reduce the signal strength as additional tests were run. The performance of the system was virtually error free up to about 6 dB of attenuation. From this point the error rate increased rapidly. This is graphed in

<sup>6</sup> Network Probe picture from the NCC web site, <http://www.netcommcorp.com>

Figure 3-3. A value of  $1\text{E-}15$  is used to represent a BER. As can be seen, the system has a small link margin; with 6 dB of attenuation, the Received Signal Strength (RSS) has dropped by 25 and the BER has increased to  $1.66\text{E-}7$ . Interestingly, the BERs recorded on the NP6650 connected to the modem (which represents the data transmitted by the Series 100) were consistently around  $5\text{E-}4$ .

Average throughputs of 4797.4 bps on the receive side and 4799.8 bps on the transmit side were determined from the BER tests. This is very close to the claimed 4800 bps data rate. Since the typical mode used is 8-bit ASCII with 1 stop bit, 1 start bit, and no parity bit per character, the actual **data** rate is on the order of 480 cps.

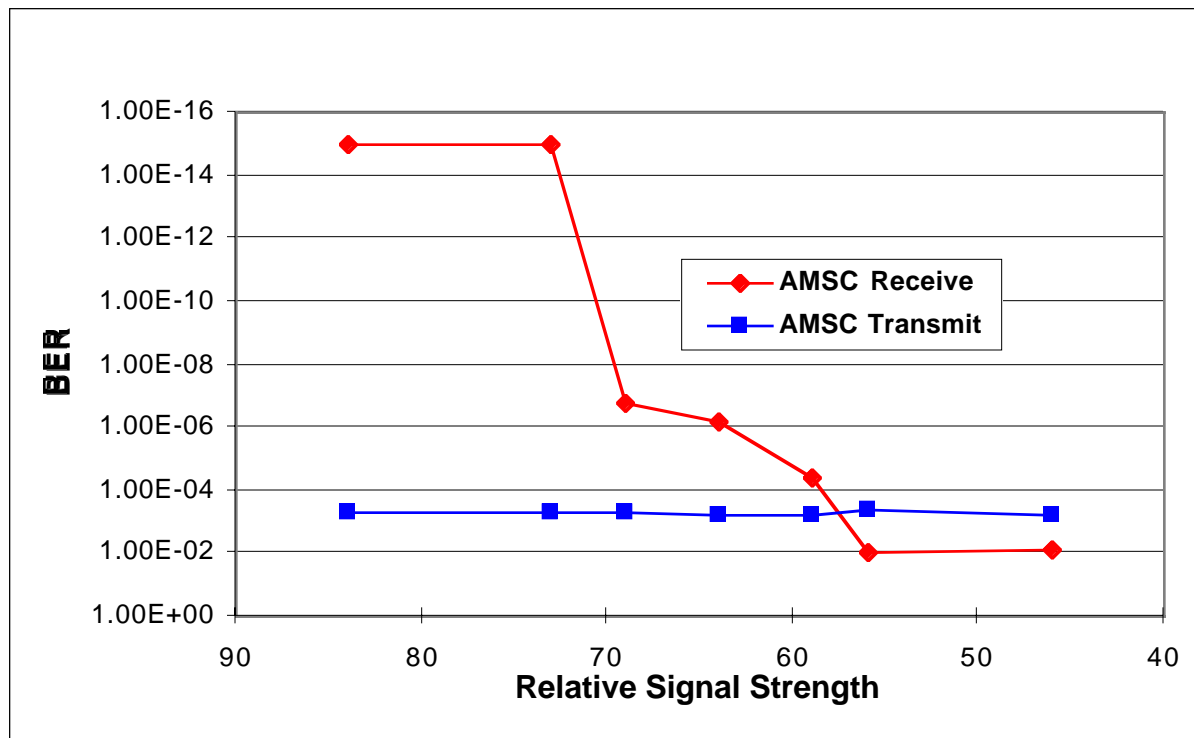


Figure 3-3 AMSC BER vs. Received Signal Strength

### 3.3 Networking Performance Testing

In addition to the data channel level testing, we also evaluated the system's performance at the transport and network layers. This was done by establishing a PPP connection over the satellite data channel and then using standard TCP/IP based software utilities to measure the performance.

#### 3.3.1 Test Bed

For these tests, a laptop computer running Windows 95 was connected to the Series 100. Using the SHIVA™ Dial-in Networking software, data calls were made to the Quickstream™ Remote Access Server (RAS) connected to the R&DC LAN in the Advanced Communications Lab. The data channel portion of the linkage is the same as described above. The SHIVA software established the PPP connection with the RAS. The login and TCP/IP connection negotiation process to the RAS typically took about 20 seconds. At this point a TCP/IP network connection

existed between the laptop and the R&DC LAN and the tests were conducted using standard TCP/IP software tools.

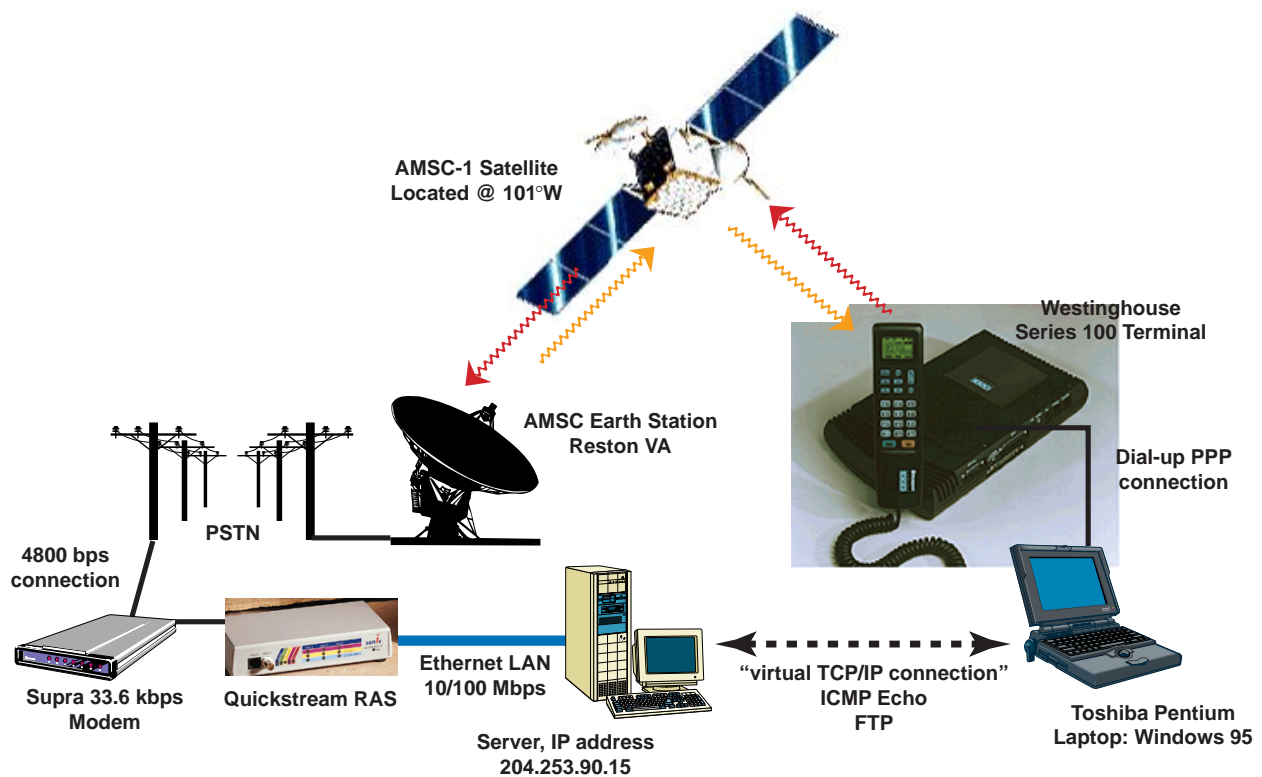


Figure 3-4 AMSC Network Performance Testing Diagram<sup>7</sup>

### 3.3.2 Latency

Latency is a measure of the end-to-end network delay. In a data transmission, this metric can be just as important as speed or bandwidth of the channel. It is affected by a variety of things. The first and most obvious would be the length of the path. Other parts of the delay would be due to other thing i.e., the earth station, buffering, system loading, and congestion. The latency metric is determined by using a network diagnostic tool called "PING." PING sends an "echo request" in the form of an ICMP data packet to the IP echo port on a remote host and displays the results for each "echo reply." The round trip time for each request and reply are recorded. The software used was the PING utility included with Windows 95. A standard 63-byte packet was used and the minimum, maximum, and average times for a large number of pings are listed in the table below. Also included in the table for comparison purposes, are the PING results when using a landline modem connection.

<sup>7</sup> Quickstream picture from Sonic Systems web site, <http://www.sonicsys.com/>

Table 3-1 PING Results for AMSC and Landline Modem

Communication System	Min. (sec)	Max.(sec)	Avg. (sec)
AMSC (2,400 bps)	1.92	2.43	2.22
AMSC (4,800 bps)	1.65	1.95	1.79
Landline (2,400 bps)	0.987	1.035	0.993

Going through the calculations below, yields a system delay (without transmission time) of approximately 1.4 seconds roundtrip.

**AMSC System Latency Calculation:**

63 byte ping packet + 40 bytes TCP/IP overhead = 103 bytes  
 103 \* 2 (transmitted in each direction) = 206 bytes  
 206 bytes \* 10 (bits/byte) = 2060 bits  
 2060 bits / 2400 bps = 0.86 sec  
 2060 bits / 4800 bps = 0.43 sec

2.22 sec - 0.86 sec = 1.36 sec  
 1.79 sec - 0.43 sec = 1.36 sec

**Landline System Latency Calculation:**

63 byte packet (as above) = 0.86 sec at 2400 bps  
 0.993 sec - 0.86 sec = 0.133 sec

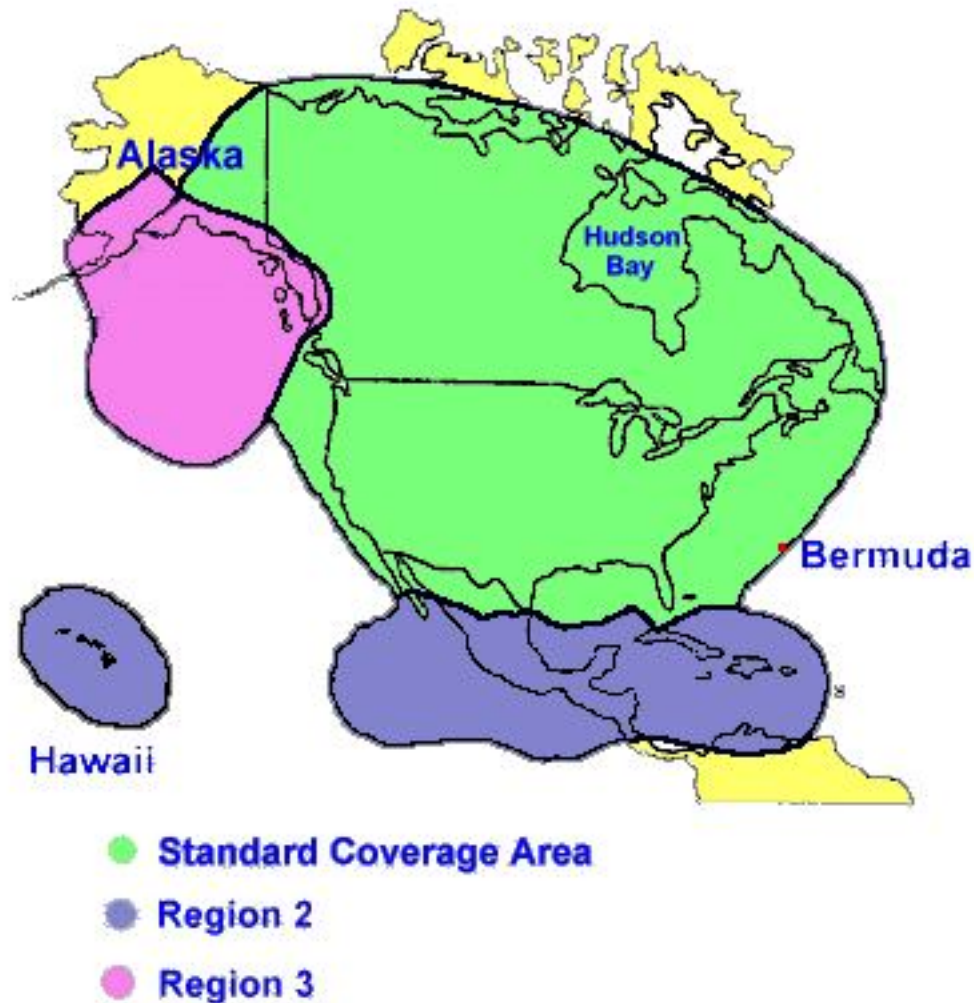
### 3.3.3 Bandwidth

Bandwidth is the width of the communication channel. While the raw data channel was measured at close to 4800 bps, the actual TCP/IP throughput is much less due to the protocol overhead. This was measured using the FTP utility under Windows 95, using a variety of file sizes from 250 Kbytes to 1 Mbyte. The average throughput for these file transfers was 3.6 kbps.

## 3.4 System Assessment

### 3.4.1 Coverage

Coverage is the geographic area in which a mobile user has access to the satellite system. Figure 3-5 below shows the projected coverage from AMSC-1. AMSC has conducted some extensive coverage verification studies. That report should be available from AMSC in the 3<sup>rd</sup> quarter of 1998. In addition, TISCOM did some coverage verification as part of their evaluation. This report was not yet available. In general however, in most areas the actual coverage exceeds the predicted coverage.



*Figure 3-5 AMSC Coverage Area*

### 3.4.2 Availability

Since AMSC uses a geostationary satellite, availability within the coverage area is not an issue. The terminals that were used on the mobile units (aircraft and ships) were all able to maintain tracking on the satellite during all maneuvers.

### 3.4.3 Reliability

In general the systems tested were all very reliable. The pre-production aeronautical units originally used experienced some mechanical failures; however, this was corrected in the later production units. Also, some of the maritime antennas were more susceptible to failure than others. This should be addressed in the TISCOM report however as TISCOM tested a variety of antenna types.

### 3.4.4 Cost

Equipment costs for AMSC terminals vary depending upon the type of terminal. A mobile or portable unit such as the Westinghouse Series 100 or Mitsubishi OmniQuest are around \$3,000. Marine terminals are between \$5,000–\$8,000. The aeronautical terminal is the most expensive at

around \$15,000. Usage costs also vary depending upon the gain of the antenna, the location, and the service provider. Typically costs are about \$1.49/minute for maritime users, and \$1.99/minute for aeronautical users. There is also generally a monthly charge of around \$40/month. Pricing for the new packet data service are not set, though it will be charged based upon the amount of data transferred, not the duration of the call.

### **3.4.5 Interoperability**

Interoperability was to be addressed as part of TISCOM's evaluation. Under the R&D Center testing, the system interconnected fine with the PSTN. Circuit switched data calls to standard modems were also successful. One difficulty we did have is that PPP connections to the SHIVA RAS were not possible; although it worked fine connecting to the Quickstream RAS. This was due to the time delay in the system, and the way SHIVA implemented the PPP in their RAS.

### **3.4.6 Ease of Use**

The system was very easy to use in the lab. Field testing was conducted by TISCOM, and results should be included in their report.

### **3.4.7 Security**

Security was not really evaluated by the R&D Center. Secure voice using a STU-III interface was scheduled to be part of the TISCOM evaluation. This was not able to be done however as AMSC had not implemented the required interface at the Earth Station. Secure web data transfers were done by the R&D Center using software encryption. The Secure Sockets Layer (SSL) standard with 128-bit encryption was used for secure web connections. This however is not authorized by the NSA to secure classified traffic.

## **4. Conclusions**

AMSC works well for both voice and data communications. Although not specifically tested here, the indications are that the voice quality is good. As with any geostationary satellite system there is the half-second roundtrip delay to contend with during conversations, but this is usually acceptable with some practice.

The system worked quite well for data communications. The raw channel rate of 4,800 bps provides a TCP/IP throughput of about 3.6 kbps. There is a roundtrip system delay of about 1.4 seconds. This delay is most noticeable when conducting small back-and-forth data transfers such as database queries and web surfing; however, AMSC was used quite successfully for just this type of operation in the OWL project. A typical database entry and response cycle took about 18 seconds. CALQuest terminals continue to be used for this purpose in the First District (installed on four Falcon jets).

The other aspects of the system that were tested were all satisfactory. Coverage, availability, and reliability were all good. Interoperability was generally good, with the exception of the difficulty with the Shiva RAS. Ease of use and security were not evaluated as part of our testing. Additional information on AMSC system performance should be contained in the AMSC coverage report and TISCOM testing report when they are available. Also, the new packet data service could provide better and more cost-effective data service. This will need to be looked at when available.

## 5. References

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4. Gregory Johnson and Mark Wiggins, "[Improved Coast Guard Communications using Commercial Satellites and WWW Technology](#)," June 1997, Proceedings of IMSC '97, Pasadena CA.
5. AMSC's web site at <http://www.skycell.com/>
6. Westinghouse Wireless Solutions Co. web site at <http://165.117.246.101/index.html>
7. CAL Corp web site at <http://www.calcorp.com/satcg.htm>
8. NCC Web site at <http://www.netcommcorp.com/>
9. Sonic Systems web site at <http://www.sonicsys.com/>



## 6. Acronyms

AC	Alternating Current
AMBE	Adaptive Multi-Band Encoding
AMSC	American Mobile Satellite Company
AORE	Atlantic Ocean Region East
AORW	Atlantic Ocean Region West
BER	Bit Error Rate
BERT	Bit Error Rate Test
bps	bits per second
Bps	Bytes per second
C	Celsius
CER	Character Error Rate
CES	Coast Earth Station
cm	centimeter (0.01 m)
cps	characters per second
CONUS	CONtinental United States
dB	Decibel
DC	Direct Current
DTMF	Dual-Tone Multi-Frequency
DM	Degraded Minutes
fax	facsimile
FCC	Federal Communications Commission
FEC	Forward Error Correction
GES	Ground Earth Station
GHz	Giga-Hertz (1,000,000,000 Hertz)
GSM	Global System for Mobile communications
Hz	Hertz (cycles per second)
ICMP	Internet Control Message Protocol
Inmarsat	International Maritime Satellite Organization
Intelsat	International Telecommunications Satellite Organization
IOR	Indian Ocean Region
IP	Internet Protocol
K	Kelvin
kbps	kilobits per second (1,000 bps)
Kbyte	Kilobyte, file size of 1024 bytes
kg	kilogram (1,000 grams)
kHz	kiloHertz (1,000 Hertz)
LAN	Local Area Network
lbs	U.S. pounds
LES	Land Earth Station
m	meter

Mbyte	Megabyte, file size of 1024 Kbytes
MES	Mobile Earth Station
MHz	MegaHertz (1,000,000 Hertz)
mm	millimeter (0.001 m)
ms	millisecond (0.001 second)
MSS	Mobile Satellite Service
mW	milliWatt (0.001 W)
NCC	Network Control Center
NCS	Network Control Station
NiCad	Nickel-Cadmium
NM	Nautical Miles
NSA	National Security Agency
OIS	Operational Information System
O-QPSK	Offset Quadrature Phase Shift Keying
OWL	Operational Web Link
POR	Pacific Ocean Region
PPP	Point-to-Pont Protocol
PSTN	Public Switched Telephone Network
R&D	Research and Development
RAS	Remote Access Server
RHCP	Right-Hand Circular Polarization
RX	Receive
SCADA	Supervisory, Control, And Data Acquisition
SCPC	Single Channel Per Carrier
SES	Severely Errored Seconds
SIM	Subscriber Identity Module
SSL	Secure Sockets Layer
TCP	Transmission Control Protocol
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TISCOM	Telecommunication & Information System COMmand
TMI	Telesat Mobile. Inc.
TX	Transmit
Vac	Volts, AC
Vdc	Volts, DC
W	Watt
WRC	World Radio Conference

## **Appendix A**

- A-1      Westinghouse Series 100 Terminal Specifications**
- A-2      Westinghouse Series 1000 Marine Satellite Telephone System Features and Specifications**
- A-3      Westinghouse HVDM Product**
- A-4      CALquest Aeronautical AMSC Terminal**

## A-1 Westinghouse Series 100 Terminal Specifications

The transceiver is the heart of Westinghouse satellite telephone systems. Its sleek design is rugged and built to withstand harsh environments. Westinghouse satellite telephone systems require between 11.5 and 15.6 volts DC, and draws approximately 2 amps in receive mode and 6 amps to transmit. The transceiver orchestrates the functions of the system and becomes the hub of a versatile communications office by simply connecting the appropriate peripherals. An RJ-45 jack provides the interface for the handset, allowing for voice and programming capabilities. A standard RJ-11 fax interface connects to any Group III fax machine. A DB-25 data port interfaces to a PC or any other mobile data device supporting circuit switched data services. And a DB-15 interface facilitates a GPS module, Messaging Terminal Equipment, remote Data Terminal Equipment or access to an external PC.

### Transceiver Technical Specifications

#### Physical Characteristics

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<b>Dimensions</b>	12"L x 7"W x 2"H
	30cm x 17.8cm x 5.4cm
<b>Weight</b>	7 lb
	3.2Kg
<b>Options</b>	Packet Data
	Facsimile

#### Performance Specifications

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<b>Frequency Range</b>	1525-1559 MHz (receive)
	1626.5-1660.5 MHz (transmit)
<b>Channel Spacing</b>	6 kHz
<b>Operating Current</b>	2A (receive)
<b>Operating Temperature</b>	-20 0 F to 130 0 F
<b>Power Output</b>	12.5 dBW to 16.5 dBW

**Standard Transceiver Connections**

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Multifunction Handset	External Speaker
Hands-Free Microphone	PC/data terminal
Global Positioning Module and/or Automatic System Controller	

**Optional Equipment**

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Cellular transceiver	FX-10 Fax/Telephony Card
ClearSpeech™	

## A-2 Westinghouse Series 1000 Marine Satellite Telephone System Features and Specifications

Westinghouse, a leader in satellite communications for over 25 years, proudly introduces **Wavetalk™**, the marine version of the Series 1000 Mobile Satellite Telephone System. **Wavetalk™** brings private digital marine communications to both commercial mariners and pleasure boaters without the high price tag or bulky equipment of other satellite telephone systems. **Wavetalk™** provides voice, dispatch radio, facsimile (fax) and data satellite communications and can operate throughout virtually all of North and Central America, the northern tip of South America, the entire Caribbean, and Hawaii. **Wavetalk™** is digital, thus totally private and needs no operator assistance. Both outgoing and incoming calls are dialed directly through a geostationary communications satellite positioned 23,000 miles above the earth, to or from any worldwide telephone number. **Wavetalk™** operates on satellites owned and operated by American Mobile Satellite in the U.S., Telecomunicaciones de Mexico in Mexico, and TMI Communications Pty. Ltd. in Canada. The ground stations that control satellite telephone operations for these companies were also designed and built by Westinghouse. With **Wavetalk™**, you can communicate anywhere within the satellite coverage area with virtually anywhere in the world.

Through state-of-the-art digital satellite technology, **Wavetalk™** sports not only the smallest but the most lightweight antenna designed specifically for the marine world. Even more impressive is the fact that **Wavetalk™** has been designed to avoid the use of many complicated and fragile moving parts required by stabilized satellite phone antennas. Thus, a compact, lightweight antenna with increased reliability.

With flame retardant, low smoke, low toxicity, UV protected antenna cabling as standard equipment, **Wavetalk™** eases the concerns of the safety conscious boater, while also providing ample cable lengths to properly position the antenna. In addition, the **Wavetalk™** antenna is easy to mount, either flush to the deck or on a standard 1-inch marine mount. A marine conformal coated antenna board and stainless steel antenna mounting hardware top off the design of the **Wavetalk™** antenna insuring corrosion-free use. And Westinghouse stands behind **Wavetalk™** with a one year factory warranty.

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### **Wavetalk™ Features**

#### **Components**

The **Wavetalk™** telephone comprises four main components: the transceiver, the antenna electronics unit, the handset, and the contoured antenna with its windswept design.

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#### **Satellite Providers**

**Wavetalk™** operates on satellites owned and operated by American Mobile Satellite Corporation in the U.S., Telecomunicaciones de Mexico in Mexico, and TMI Communications Pty. Ltd. in Canada. Satellite coverage areas include North America and Central America extending 200

miles out to sea, the entire Caribbean, the northern tip of South America, Hawaii and its surrounding waters.

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## Satellite Service Providers

To operate, **Wavetalk**<sup>™</sup> must be commissioned on a satellite through a satellite service provider. Commissioning, airtime and equipment can be purchased from satellite service providers and their dealers, located throughout the U.S., Canada, Mexico and the Caribbean. For service and dealer information, please call the Westinghouse Customer Support Center at 1-800-851-4807.

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## Satellite Communications Services

**Wavetalk**<sup>™</sup> is capable of providing voice, dispatch radio, data and fax satellite communications. All communications are private; each call is protected from "eavesdroppers" by using dedicated frequencies and digitally scrambling the transmissions.

The voice quality is similar to that of a digital cellular telephone; however, all satellite communications experience a slight delay in transmission.

For dispatch radio, multiple satellite telephones can be linked as part of a private communication group, similar to a VHF/HF radio group. Conversations, too, are totally private. This capability is currently available on American Mobile Satellite Corporation's and TMI Communication's satellite systems.

Data is standard modem-to-modem interfacing at 2400 baud or 4800 baud depending on the satellite service provider.

Faxes can be sent and received by either personal computer (PC), containing facsimile software, or by fax machine. There are two different facsimile transmission methods, depending on which satellite service the phone is commissioned. The two methods are: (1) "*direct*" faxing via a standard fax machine connected to the transceiver, or (2) a "*store-and-forward*" method using a fax machine or a PC. **Wavetalk**<sup>™</sup> supports both methods.

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## Built-in Interfaces

An RS-232/DB25 pin data port is located on the transceiver, and is used to connect a PC or data terminal. To make this connection, an RS-232 cable from the PC or data terminal is needed. Since the phone is the modem, there's no need for a separate modem card in your PC. The phone supports most Hayes compatible AT commands. **Wavetalk**<sup>™</sup> supports standard consumer communications software such as Procomm, America Online, etc.

A GPS port, located on the transceiver, accepts an NMEA-0183 GPS data stream (strings GGA & ZDA), allowing the satellite transceiver to receive GPS data and display it on the handset.

An external speaker jack allows the caller to connect and use an external speaker while simultaneously using the handset.

An interface called a horn alert is provided for incoming calls to sound a horn, ring a bell, or activate a flashing light.

The standard **Wavetalk**<sup>™</sup> handset supports "Dispatch Radio" through handset commands. However, an optional handset with a push-to-talk button located on it's side is also available. (Dispatch radio is referred to by American Mobile Satellite Corporation as *Skycell Plus* Dispatch Service.)

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## Other Optional Features

An optional Westinghouse FX-10 card allows the user to connect a cordless phone, touch-tone phone (with a current draw of up to 30ma), or a loop-start Private Branch Exchange (PBX) trunk line to **Wavetalk**<sup>™</sup>. This allows the user to retain the handset as part of the system while being connected to an extension phone or PBX trunk line.

An optional Satellite Telephone Interface provides the user with the ability to tie **Wavetalk**<sup>™</sup> to multiple touch-tone phones (if the current draw is less than 51ma) or a PBX loop-start or ground-start system. When using this option, however, the handset must be removed from the **Wavetalk**<sup>™</sup> system and the Satellite Telephone Interface connected between the handset port and the PBX trunk line or suite of touch-tone phones.

An optional 3-watt cellular transceiver connected to the satellite transceiver allows **Wavetalk**<sup>™</sup> to become a dual mode cellular/satellite telephone on one handset. The dual mode phone can be preset to search for a cellular signal first, then switch to satellite if one is not found. For this operation, the cellular transceiver requires activation through a cellular service provider and the addition of a cellular antenna.

Packet data software, for transmitting X.25 packet data streams, will be available later this year.

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## Antennas

The **Wavetalk**<sup>™</sup> antenna, with its windswept look and patented design, was developed specifically for the marine environment. It is the smallest and lightest marine satellite telephone antenna available, about the size of a bicycle helmet, and weighing only 2.2 pounds. Unique software algorithms insure satellite tracking from calm to heavy seas. Marine features include: a marine conformal coated antenna board, gold plated connector pins, marine grade stainless steel hardware, and safety rated antenna cables that are fire retardant, low-smoke and low-toxicity, and are UV protected. Two different antenna models are available: the standard **Wavetalk**<sup>™</sup> medium gain antenna and the **Wavetalk PLUS**<sup>™</sup> high gain antenna\*.

\*Some satellite per-minute airtime rates are based on antenna gain. Please contact your satellite service provider for this information.

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## **Frequently Asked Questions About Wavetalk™**

### **What is Wavetalk™?**

**Wavetalk™** is a marine satellite telephone system that allows you to make or receive direct dial calls from within the satellite coverage area to or from anywhere in the world.

### **Where can I buy Wavetalk™?**

For your nearest dealer and satellite service provider, call the Westinghouse Customer Support Center, toll free, at 1-800-851-4807.

### **How much does Wavetalk™ cost?**

The Manufacturer's Suggested Retail Price for **Wavetalk™**, the medium gain system, is \$4,995(U.S.) and for **Wavetalk PLUS™**, the high gain system, is \$5,335(U.S.).

### **What are the air time costs?**

Air time rates, activation and monthly access fees are set by the satellite service providers. Current U.S. satellite air time rates for **Wavetalk™** range from approximately \$.99 to \$1.49 per minute. This includes long distance service for calls terminated in the U.S. and Canada.

### **Is it complicated to use the Wavetalk™ telephone?**

No, it's as easy to use as a cellular phone, just dial the complete telephone number, domestic or international, and press the "Send" key. When you finish the call, press the "end" key. For incoming calls, when the phone rings, just pick up the handset from the cradle or press the "send" key.

### **What data services does Wavetalk™ support?**

**Wavetalk™** provides the ability to communicate via personal computer to e-mail, on-line services, or dial up an Internet service provider. **Wavetalk™** supports any modem to modem data transfer.

### **How does facsimile work and where is it available?**

**Wavetalk™** supports two methods of faxing: "direct", and "store and forward."

*Direct* faxing requires the installation of an optional Westinghouse FX-10 card. Once installed, a group III fax machine can be connected directly to the RJ-11 fax port. To send a fax just dial the number on your fax pad and press the send key. This method is currently available on the Telecomunicaciones de Mexico satellite system.

*Store-and-forward* faxing requires a separate software package or a separate hardware module. To send a fax using a PC, the *store-and-forward* software package is needed, in addition to standard PC fax software. The PC is then connected directly to the satellite transceiver's RS-232 data port. To send a fax using a Group III fax machine, the *Store-and-forward* hardware module is needed. This module is connected between the fax machine and the satellite transceiver's RS-232 data port. To send a fax dial the number on your PC or fax pad and press the send key.

For customers commissioned on either American Mobile Satellite Corporation or TMI Communications satellites, please contact your satellite service provider for the facsimile service method and service availability date.

**How does the Wavetalk™ antenna track the satellite?**

The **Wavetalk™** antenna tracks, or rotates, within its molded shell 360 degrees in azimuth (horizontally) with a wide angle elevation beam, 45 degrees, pointed upward in the direction of the satellite. A rate sensor is used in the antenna to sense movement. Once movement is sensed, the antenna is turned left or right to maintain track of the satellite.

**Why does Wavetalk™ work without stabilization?**

Stabilization platforms have fragile moving parts and a relatively slow reaction time. The unique design of the **Wavetalk™** antenna eliminates the need for stabilization, entirely. The 45 degree wide elevation beam in conjunction with the 360 degree azimuth tracking system turn at a rate of 70 degrees per second, enabling the **Wavetalk™** antenna to establish contact and continually track the satellite as a boat pitches, rolls and yaws. While technical specifications require optimum satellite tracking to be maintained from 15 to 60 degrees above the horizon, actual testing has resulted in satellite tracking from 5 to 75 degrees above the horizon. To illustrate the antenna's superb tracking ability in severe conditions, Westinghouse tested **Wavetalk™** mounted on a 30 foot boat in 12 to 15 foot seas at an approximate 10 degree look angle to the satellite. Satellite tracking was continually maintained.

**How far can the Wavetalk™ antenna be placed from its electronic components and handset?**

Standard **Wavetalk™** antenna cabling is 40 feet long with optional 55 foot antenna cables available as special order items. **Wavetalk PLUS™** antenna cabling is 18 feet long. In addition, the handset on either system can be mounted up to 30 feet from the transceiver. Thus, for **Wavetalk™** the overall distance from the antenna to the handset, less routing obstructions, can be up to 85 feet, and for **Wavetalk PLUS™** the overall distance from the antenna to the handset, less routing obstructions, can be up to 48 feet.

**How does the Wavetalk™ antenna mount to a vessel?**

The antenna base can be mounted flush to the flat surface of the deck, or to a standard 1-inch by 14 thread marine antenna mount.

**Are the antenna cables easy to route through a vessel?**

The antenna cables are relatively flexible and easy to route. The RF cable is 0.5 inches in diameter and is pre-terminated with a TNC connector on one end and an SMA connector on the other. The control/power cable is 0.25 inches in diameter and is unterminated on the antenna connection end for easy routing. A field-installable antenna connector is provided.

**Why is the Wavetalk™ antenna so much smaller than other marine antennas?**

Since American Mobile Satellite Corporation, Telecomunicaciones de Mexico, and TMI Communications have launched extremely powerful satellites, less antenna gain is needed, so antennas can be smaller and still maintain satellite tracking. However, **Wavetalk™** with its

patented antenna design, offers not only the smallest marine antenna, but the lightest one as well in either medium or high gain models.

**How does Wavetalk™ compare to other satellite telephone products?**

No other marine satellite telephone is comparable to **Wavetalk™** in antenna design, size or weight. Similar or less expensive products may be offered but are either heavier, bulkier in size, contain more moving and fragile parts, or are not marine warranted. Some satellite systems may offer faster data rates, but at a substantially higher cost for hardware and air-time, along with bulkier antennas.

**What about product safety?**

**Wavetalk™** is designed to shut down in case of overheating or RF power overload. **Wavetalk™** displays all proper caution and warning labels required by law. Fuses are provided for the 12 VDC and ignition sense cables. **Wavetalk™** antenna cables are flame retardant, low-smoke, low-toxicity and UV protected. And, **Wavetalk™** has been independently tested by Underwriters Laboratories, Inc. and is UL/CUL listed in the U.S. and Canada.

Please call the Westinghouse Customer Support Center at 1-800-851-4807 if you have additional questions or comments concerning **Wavetalk™**.

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**Wavetalk™ Specifications**

**Communication  
Modes**

Voice	Full duplex digital voice
	Half duplex digital voice - dispatch
	Cellular analog voice (option)
Data	2400/4800 bps
Fax	PC or Group III facsimile

**Systems  
Specifications**

Transmit Frequencies	1626.5 - 1660.5 MHz
Receive Frequencies	1525.0 - 1559.0 MHz
G/T	<i>Wavetalk_</i> -16 dB/°K from 15° - 60° elevation

		<i>Wavetalk</i> PLUS_	-13.5 dB/∞K from 15∞ - 60∞ elevation
EIRP			12.5 -16.5 dBW
Polarization			Right-hand circular (RHCP)
Channel Spacing			6.0 kHz
<b>Interface Specifications</b>			
Voice			RJ-45, Handset supports satellite voice, dispatch radio, and cellular;
			RJ-11, touch-tone telephone interface (option); push-to-talk handset (option)
Data			DB-25, RS-232
			Hayes compatible AT Command Set
Fax	External		DB-25, RS-232; AMSC, TMI
	Internal		RJ-11/FX-10 card; Telecomunicaciones de Mexico
Power			12 VDC Nominal (11.5 - 15.6 V range)
			2A receive, 6.5A transmit

**Physical Specifications**

Antenna - Dome			
	Size (LWH)		10.4" L x 9.4" W x 6.5" H oval (26.0 cm x 24.0 cm x 16.5 cm)
	Weight		2.2 lb (1 kg)
	<i>Wavetalk</i> _	Cables	RF = 0.5" dia (1.27 cm) pre-terminated with TNC connectors;
			Control/Power = 0.25" dia (0.63 cm) unterminated with pins attached
		Length	40 ft (12.2 m), 55.0 ft (16.8 m) (option)
	<i>Wavetalk</i> PLUS_	Cables	RF = 0.4" dia (1.02 cm) pre-terminated with SMA/TNC connectors

Control/Power = 0.25" dia (0.63 cm) unterminated with pins attached	
Length	18.0 ft (5.5 m)
Antenna	
Electronics Unit	
Size (LWH)	9.0" L x 7.0" W x 2.5" H (22.6 cm x 17.8 cm x 6.4 cm)
Weight	7.0 lb (3.2kg)
Transceiver	
Size (LWH)	12.0" L x 7.0" W x 2.0" H (30.5 cm x 17.8 cm x 5.3 cm)
Weight	7.5 lb (3.4 kg)
Handset	
Size (LWH)	
Weight	7.75" L x 1.5" W x 1.5" H (19.7 cm x 3.8 cm x 3.8 cm)
Cable	0.4 lb (0.2 kg)
	30.0 ft (9.2 m) - 6.0 ft coil and 24.0 ft straight
Cellular Module (option)	
Size (LWH)	8.0" x 3.3" x 1.0" (20 cm x 8.5 cm x 2.8 cm)
Weight	1.3 lb (0.6 kg)

**Dynamic Specifications**

Antenna Turning Rate	70°/sec, maximum
Antenna Acceleration Rate	500°/sec≤, maximum

**Operating Temperatures**

-22°F to +130°F (-30°C to + 55°C)

## A-3 Westinghouse HVDM Product

### What Is An HVDM?

The Westinghouse HVDM (Hybrid Voice/Data Mobile Terminal) is a new product being offered by Westinghouse which provides both Packet Switched and Circuit Switched satellite communications in a single mobile product. The Westinghouse HVDM product is now available and HVDM product users may subscribe to any or all of the available satellite services, including:

- Voice
- Circuit switched data
- Synchronous X.25 packet data
- Asynchronous PAD packet data
- Group III FAX (not available on all networks)
- Net Radio Dispatch
- Dual Mode Cellular

The Westinghouse HVDM product capability is intended for users who need the power and flexibility of multiple data transmission protocols. In addition, the product lets users switch between satellite Packet Switched data services and voice/dispatch services. For such users, the Westinghouse HVDM product is a cost-effective solution that minimizes equipment investment and installation while providing a full-coverage, full-service communications system. HVDM capabilities are available in conjunction with all Westinghouse satellite telephone configurations for land mobile, fixed site, transportable and marine applications.

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### How Does User Data Equipment Interface To The HVDM?

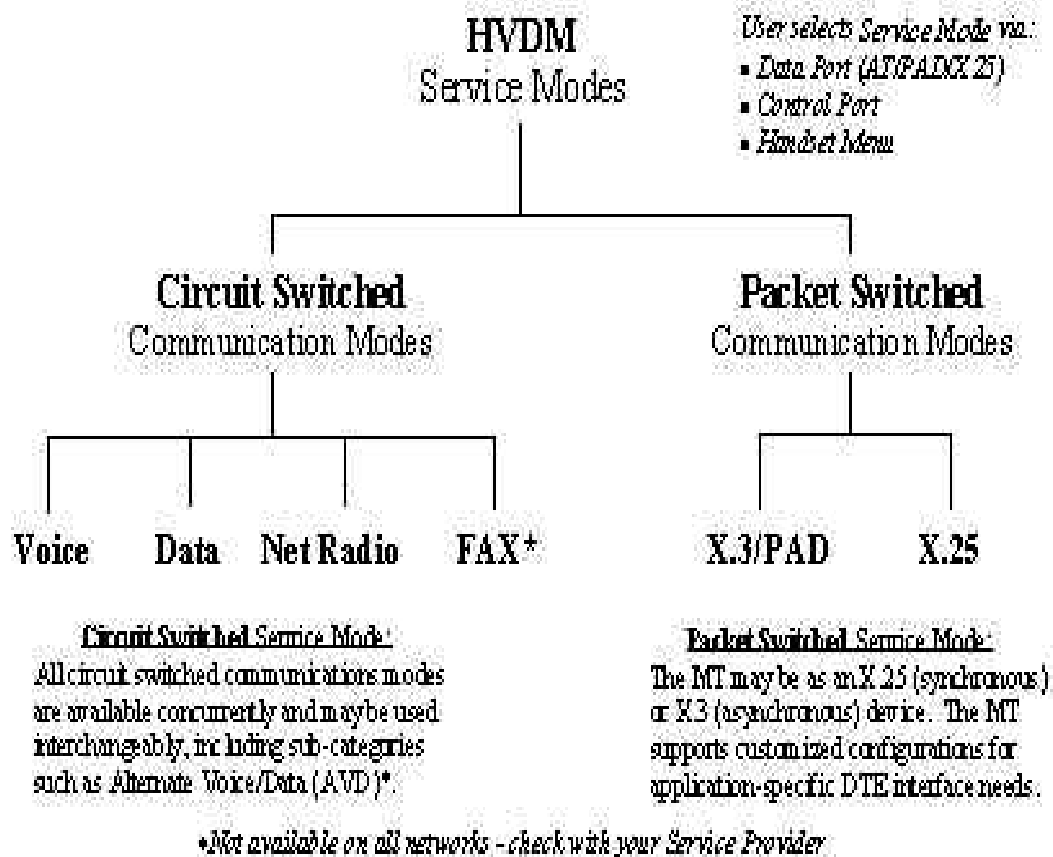
The Westinghouse HVDM product has two industry standard data ports that provide interfaces for Personal Computers or other user Data Terminal Equipment (DTE). One communications port provides three standard data interfaces: (1) a Hayes-compatible data modem for circuit switched applications; (2) synchronous X.25 data communications; or, (3) asynchronous (X.3) data communications for Packet Switched data applications. The second port offers a combination GPS/ Control Port interface with enhanced functionality for applications developers, allowing remote or local control of the data communications equipment. Users' Guides for the data port interfaces and a list of software packages that have been tested with the Westinghouse HVDM product are available on request.

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### How Does An HVDM Work?

In the receive mode, the Westinghouse HVDM satellite transceiver is in continuous communication with the subscribed network service through a set of dedicated Signaling Channels that it monitors for incoming calls, Bulletin Boards, and network control information. On the user end, the Westinghouse HVDM product is typically operated under automatic control of application software on user DTE equipment. The application selects the mode of operation, receives incoming calls from the Westinghouse HVDM product, initiates outgoing calls, and can control the power to the HDVM.

The Westinghouse HVDM product has two Service Modes: Packet Switched Mode and Circuit Switched Mode. Each Service Mode supports multiple different Communications Modes. The Westinghouse HVDM Service Modes and Communications Modes are shown in the figure below.



While the Westinghouse HVDM is operating in one Service Mode, it is dedicated to that service mode. The HVDM may be switched to/from either Service Mode as often as needed, even on a call-by-call basis. In a given Service Mode, the Westinghouse HVDM can initiate and accept calls of the different types shown under Communication Modes.

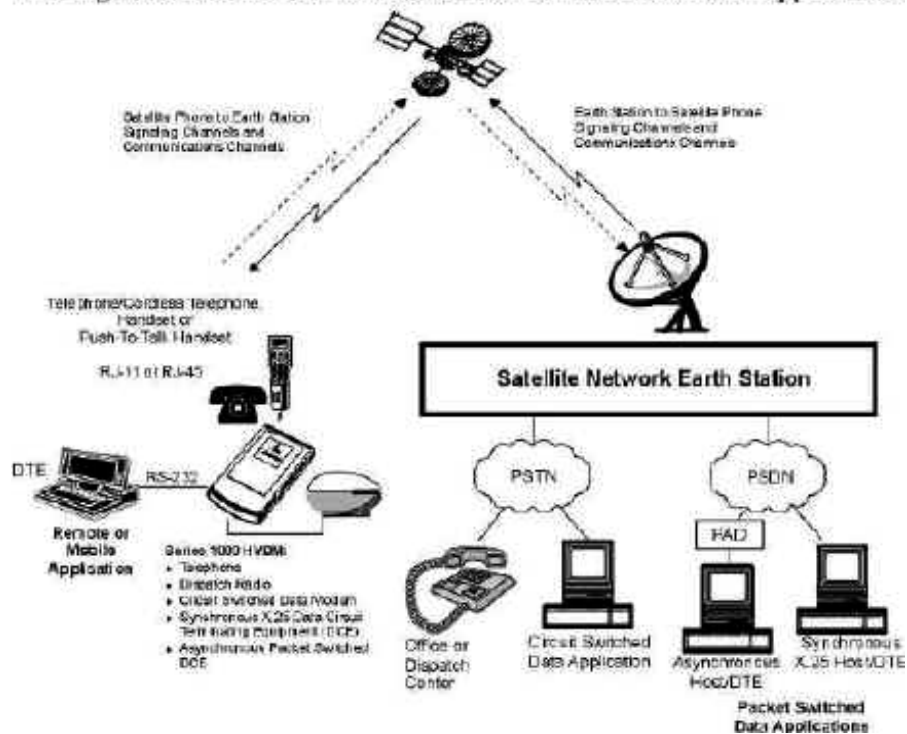
Within the Circuit Switched mode, the user may switch freely from one Communication Mode (voice, data, etc.) to any other. In Packet Data mode, the Westinghouse HVDM may be configured remotely to be either X.25 (synchronous) or X.3 (asynchronous) Communication Mode. When the Service Mode is changed (Circuit Switched to Packet Switched, or vice versa) during operation, the Westinghouse HVDM will perform a Warm Restart; it discontinues monitoring the current Signaling Channel, automatically re-boots and re-initializes itself, and acquires the new Signaling Channel for the alternate service type. The Service Mode can be changed using the handset, Data Port, or Control Port.

## Who Would Use The Westinghouse HVDM ?

The Westinghouse HVDM product is ideal for any customer who requires mobile or remote packet data operations. Because the charge for Packet Switched data transmissions is by the kilobyte rather than the minute, the cost may be only pennies a call, mounting up to substantial savings to the customer.

Typical customers who might use the Westinghouse HVDM product are those who have information to keep track of on an on-going basis. Truck GPS coordinates or cargo temperatures; oil, gas or water line pressure or capacities; SCADA applications; engine monitoring; water depth and current, are just a few examples of applications. Customers with these needs would find the Westinghouse HVDM product a valuable asset to their business. Information is collected at the site, such as a buoy for monitoring ocean currents, or pipeline monitoring station, then sent through the Westinghouse HVDM product at intervals to a monitoring station where the data is used as the customer wishes.

### Westinghouse Satellite Communications for Remote and Mobile Applications



## How Is the Westinghouse Unit Commissioned?

Customer subscription - setting up a new user's service plan, enabling optional service features, commissioning the Westinghouse HVDM product on the network, establishing the user's billing account, etc. - is a network-specific function and is therefore defined and managed by the provider of that network service.

Since the Circuit Switched and Packet Switched services and networks may be operated independently, and any user may subscribe to one or both services based on individual



communications needs, the Westinghouse HVDM product is registered and commissioned on each service separately. This process is facilitated in the Westinghouse HVDM product by allowing the dealer to configure the Westinghouse HVDM product once for both service types, and to configure or re-configure the Westinghouse HVDM for either service type independently at any time. Re-commissioning the Westinghouse HVDM on one service does not require re-commissioning it on the other service.

Satellite service for the Westinghouse HVDM is now available Norcom Networks in the United States and through TMI Communications in Canada. For more specific information on how to use the Westinghouse HVDM, call the Westinghouse Customer Support Center at 1-800-851-4807.

## A-4 CALQUEST Aeronautical AMSC Terminal

CAL CORPORATION



### SATELLITE PHONE

#### SPECIFICATIONS

CALQUEST™ was designed to provide its customers with the most advanced and highest quality mobile communications ever available.

**FEATURES INCLUDE:**

- Service Coverage of Virtually all North America, Mexico, Central America, parts of northern South America, the Caribbean, surrounding coastal waters and Hawaii.
- Direct Up-Calling
- Toll Free Number for the CALQUEST Satellite Phone
- 24 Hour A-Day Directory Assistance
- 24 Hour-A-Day Customer Assistance
- 24 Hour-A-Day Operator Services
- Voice Mail
- Call Waiting
- Call Forwarding
- Conference Calling
- No Answer Transfer

\* Certain features are available to either AMSC or TETRA Satellite Telephone Services

**KEY FEATURES AND TECHNICAL SPECIFICATIONS INCLUDE:**

- Digital Voice Transmission
- Optional Group III Fax and PC Fax
- Optional Two-Channel Phone Configuration
- Circuit-Switched Data Port with Optional Packet Mode Data Capability
- Lightweight
- Low Cost
- Easy Installation
- Antenna Steering Independent of Aircraft Navigation Systems
- Frequency Range:
  - 1525-1559 MHz (Receive)
  - 1626.5-1660.5 MHz (Transmit)
- Operating Current:
  - 6.7 AMPS @ 28 VDC - Max @ 60% Duty Cycle
  - 8 AMPS @ 28 VDC - Max Peak @ 100% Duty Cycle
- Breaker Rating - 10 AMPS
- Dimensions:
  - Transceiver: 12.5"L x 10"W x 7.5"H
  - Antenna: 28.6"L x 18.0"W x 5.95"H (including 1.7" Flange)
- Weight: Transceiver 28 lbs., Antenna 9.75 lbs.
- Antenna Gain: 10.6 db (min) - 13.5 db (max)

**QUALIFICATIONS:**

- Operating Temperature:
  - Transceiver: -15°C to +55°C
  - Antenna: -55°C to +70°C
- Plus other applicable RTCA DO-160 C Standards

For details on availability of options, please contact CAL Corporation or an authorized dealer.

**TO FIND OUT MORE:**

CALQUEST™ Satellite Phone authorized dealers are located conveniently at aviation electronics dealers and completion centers throughout the U.S. and Canada.

To find the dealer nearest you or to place your order, call 800-600-9759



An Electromagnetic Sciences Company  
 Tel. (610) 227-1771 Fax (610) 227-1781  
 Web Site: [www.calcorp.com](http://www.calcorp.com) SATCOM 1-800-600-9759  
These specifications are subject to change without notice. Printed in Canada 07/96



## **Appendix B**

### **B-1      AMSC BER Test Results**

**B-1 AMSC BER Data**

Attenuation (dB)	0	3	4	5	6	7	9
RSS (dB)	84	73	69	64	59	56	46
<b>AMSC Receive</b>							
Bit Errors	0	0	3	11	753	155.376	144.977
Character Errors	0	0	1	6	199	36.780	36.011
Bit Count	18.438.712	18.951.608	18.062.432	17.357.464	20.062.376	17.535.392	17.570.416
Character Count	2.304.839	2.368.951	2.660.054	2.169.683	2.507.797	2.191.924	2.196.302
Elapsed Time	1:20:03	1:22:16	1:18:25	1:15:21	1:27:06	1:16:16	1:16:19
Errored Time	0:00:00	0:00:00	0:00:01	0:00:06	0:01:46	1:11:52	1:14:30
Forced Errors	0	0	0	0	0	0	0
Out of Sync	9	0	7	0	9	161	45
SES	0	0	1	0	49	3.977	4.277
DM	0	0	1	1	35	76	76
BER	1.00E-15	1.00E-15	1.66E-07	6.36E-07	3.75E-05	8.92E-03	8.26E-03
CER	0.00E+00	0.00E+00	1.40E-05	2.77E-06	7.93E-05	1.69E-02	1.66E-02
Throughput	4798.7	4799.3	5653.7	4799.1	4798.7	4790.0	4796.5
<b>AMSC Transmit</b>							
Bit Errors	9.384	9.124	8.869	11.155	12.567	7.923	10.702
Character Errors	1.300	1.285	1.236	1.531	1.709	1.129	1.471
Bit Count	17.997.440	18.472.672	17.879.536	16.913.816	19.579.160	18.004.168	17.297.704
Character Count	2.249.680	2.309.084	2.228.692	2.114.227	2.447.395	2.250.521	2.167.213
Elapsed Time	1:18:09	1:20:12	1:17:25	1:13:26	1:25:01	1:18:10	1:15:06
Errored Time	5:00	0:05:22	0:05:06	0:05:08	0:05:36	0:04:58	0:05:12
Forced Errors	0	0	0	0	0	0	0
Out of Sync	128	129	120	126	139	127	127
SES	299	322	304	308	336	298	312
DM	76	77	76	69	84	74	73
BER	5.23E-04	4.95E-04	4.97E-04	6.62E-04	6.45E-04	4.40E-04	6.21E-04
CER	5.78E-04	5.58E-04	5.55E-04	7.24E-04	6.99E-04	5.02E-04	6.84E-04
Throughput	4797.8	4798.6	4798.0	4798.5	4797.9	4798.6	4809.6